

PORTABLE RADIO TERMINAL AND AFC CONTROL METHOD**BACKGROUND OF THE INVENTION****FIELD OF THE INVENTION:**

5 The present invention relates to a portable radio terminal and AFC control method which realize AFC (Automatic Frequency Control) for automatically controlling the oscillation frequency of an oscillator.

DESCRIPTION OF THE PRIOR ART:

10 Conventional portable radio terminals applied to systems such as QPSK and WCDMA incorporate low-cost, low-precision oscillators (to be referred to as mobile station oscillators hereinafter) in order to reduce the cost of the portable radio terminal. The portable radio
15 terminal performs AFC (Automatic Frequency Control) for detecting a frequency shift in the mobile station oscillator on the basis of a received wave sent from a higher-frequency-precision base station, feeding back the detected shift, and adjusting the frequency of the mobile
20 station oscillator.

 An example of conventional AFC control methods is disclosed in Japanese Unexamined Patent Publication No. 10-229491. In this prior art, correction data for correcting an AFC signal to be fed back to a mobile
25 station oscillator is stored in a memory. The correction

data is read out from the memory in accordance with the lapse of time so as to keep the output frequency of one mobile station oscillator constant with respect to the lapse of time after power-on operation.

5 In this prior art, however, large power is consumed because AFC operation continues after power-on operation. If the oscillation frequency of the oscillator greatly shifts, the signal timing shifts in an idle time, and reception may fail. High-precision frequency control is
10 not achieved, and a malfunction may occur. Further, it is difficult to correct a frequency shift or rapidly follow phasing.

SUMMARY OF THE INVENTION

 The present invention has been made in consideration
15 of the above situations in the prior art, and has as its first object to provide a portable radio terminal and AFC control method which intermittently operate and control an AFC control system, shorten the intermittent operation period to frequently perform AFC operation for a large
20 frequency shift, and extend the intermittent operation period and AFC operation stop period for a small frequency shift, thereby realizing high-precision AFC operation while reducing power.

 It is the second object of the present invention to
25 provide a portable radio terminal and AFC control method

which change intermittent operation into the intermittent operation of the whole radio mobile station in an idle time, thereby preventing a signal timing shift and a reception failure in an idle time when the oscillation
5 frequency of an oscillator greatly shifts.

It is the third object of the present invention to provide a portable radio terminal and AFC control method which can update a frequency shift value to the oscillator to realize high frequency precision without any
10 malfunction when shifts in the same direction are detected N times (N: arbitrary number) because the frequency shift value includes many errors for a sufficiently small frequency shift.

It is the fourth object of the present invention to
15 provide a portable radio terminal and AFC control method which monitor the reception quality or sync state, determine whether to input an AFC signal to the oscillator, and can avoid an AFC malfunction caused by low reliability such as a low reception quality or poor sync state.

20 It is the fifth object of the present invention to provide a portable radio terminal and AFC control method which monitor the reception quality, when the transmission channel state is poor, shorten the AFC intermittent operation period because the frequency may greatly shift
25 or phasing is to be followed, and can correct a frequency

shift or rapidly follow phasing.

To achieve the above objects, according to the first aspect of the present invention, there is provided a portable radio terminal for realizing automatic frequency control (AFC) for automatically controlling an oscillation frequency of an oscillator, comprising means for intermittently performing AFC operation, and means for shortening an AFC operation stop period when a frequency shift of the oscillation frequency is large.

10 According to the second aspect of the present invention, there is provided a portable radio terminal, further comprising means for extending the stop period in intermittent operation of the AFC operation when the frequency shift of the oscillation frequency is small.

15 According to the third aspect of the present invention, there is provided a radio terminal, wherein the intermittent operation includes not only the AFC operation but also operation stop of the portable radio terminal.

According to the fourth aspect of the present invention, there is provided a portable radio terminal for realizing automatic frequency control (AFC) for automatically controlling an oscillation frequency of an oscillator, comprising means for updating a frequency shift to the oscillator when the frequency shift of the oscillation frequency is smaller than a predetermined

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value and frequency shifts in the same direction are detected a predetermined number of times.

According to the fifth aspect of the present invention, there is provided a portable radio terminal for realizing automatic frequency control (AFC) for automatically controlling an oscillation frequency of an oscillator, comprising means for monitoring a reception quality or sync state and determining in accordance with a result whether to input a frequency shift value to the oscillator.

According to the sixth aspect of the present invention, there is provided a portable radio terminal, further comprising means for performing the AFC operation at a predetermined short period when the portable radio terminal fails in decoding, does not detect any pilot signal, or detects a step out state.

According to the seventh aspect of the present invention, there is provided an AFC control method of realizing automatic frequency control (AFC) for automatically controlling an oscillation frequency of an oscillator, comprising intermittently performing AFC operation, and when a frequency shift of the oscillation frequency is large, shortening an AFC operation stop period.

According to the eighth aspect of the present

invention, there is provided an AFC control method, wherein when the frequency shift of the oscillation frequency is small, the stop period in intermittent operation of the AFC operation is extended.

5 According to the ninth aspect of the present invention, there is provided an AFC control method, wherein the intermittent operation includes not only the AFC operation but also operation stop of a portable radio terminal.

10 According to the 10th aspect of the present invention, there is provided an AFC control method of realizing automatic frequency control (AFC) for automatically controlling an oscillation frequency of an oscillator, comprising updating a frequency shift to the oscillator
15 when the frequency shift of the oscillation frequency is smaller than a predetermined value and frequency shifts in the same direction are detected a predetermined number of times.

 According to the 11th aspect of the present invention,
20 there is provided an AFC control method of realizing automatic frequency control (AFC) for automatically controlling an oscillation frequency of an oscillator, comprising monitoring a reception quality or sync state and determining in accordance with a result whether to
25 input a frequency shift value to the oscillator.

According to the 12th aspect of the present invention, there is provided an AFC control method, wherein the AFC operation is performed at a predetermined short period when decoding fails, no pilot signal is detected, or a
5 step-out state is detected.

As is apparent from the above aspects, according to the present invention, an AFC control system is intermittently operated and controlled. When the frequency shift is large, the intermittent operation
10 period is shortened, and AFC operation is frequently performed. When the frequency shift is small, the intermittent operation period and AFC operation stop period are extended. Accordingly, high-precision AFC operation can be realized while power is reduced.

15 According to the present invention, intermittent operation is changed into the intermittent operation of the whole radio mobile station in an idle time. When the oscillation frequency of an oscillator greatly shifts, a signal timing shift and a reception failure can be
20 prevented in an idle time.

According to the present invention, the frequency shift value includes many errors when the frequency shift is sufficiently small. Thus, when shifts in the same direction are detected N times (N: arbitrary number), a
25 frequency shift value to the oscillator can be updated to

realize high frequency precision without any malfunction.

According to the present invention, the reception quality or sync state is monitored, and whether to input an AFC signal to the oscillator is determined. An AFC
5 malfunction caused by low reliability such as a low reception quality or poor sync state can be avoided.

According to the present invention, the reception quality is monitored. When the transmission channel state is poor, the AFC intermittent operation period is
10 shortened because the frequency may greatly shift or phasing is to be followed. This enables correcting a frequency shift or rapidly following phasing.

The above and many other objects, features and advantages of the present invention will become manifest
15 to those skilled in the art upon making reference to the following detailed description and accompanying drawings in which preferred embodiments incorporating the principle of the present invention are shown by way of illustrative examples.

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BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram for explaining an embodiment of an AFC control method for a portable radio apparatus according to the present invention;

Fig. 2 is a flow chart showing an AFC control flow in
25 the first embodiment of the present invention;

Fig. 3 is a timing chart for explaining intermittent operation and a related operation in the present invention; and

Figs. 4 to 7 are flow charts showing the AFC control flow of a portable radio terminal in each of the second to fifth embodiments of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Several preferred embodiments of the present invention will be described in detail below with reference to the accompanying drawings.

Fig. 1 is a block diagram for explaining an embodiment of an AFC control method for a portable radio apparatus according to the present invention. Fig. 1 shows a base station 101 and a radio mobile station (hereinafter called mobile station) 104 applied to the embodiment. The schematic arrangement of the mobile station 104 is shown by the block diagram.

The mobile station 104 is constituted by a mobile station radio unit 105, an A/D converter 106, a signal processing unit 107 having a DSP, gate array, and standard cell, a control unit 116 having a CPU, an output unit 108 such as a loudspeaker, a mobile station oscillator 109, a mobile station PLL unit 110, an LPF (Low Pass Filter) 111, and an AFC D/A 112.

The signal processing unit 107 is made up of a mobile

station data processing unit 113, frequency shift
detection unit 114, TCXO AFC unit 115, and control unit
116. The mobile station data processing unit 113 is
comprised of a sync detection unit 117, demodulation unit
5 118, deformat unit 119, decoding unit 120, and power
detection unit 121.

The operation of the portable radio terminal 104 in
the embodiment will be described with reference to Fig. 1.
A digital signal 122 modulated in the base station 101 is
10 transmitted from a base station antenna 102. A radio wave
123 transmitted from the base station antenna 102 is
received by a portable radio terminal antenna 103, and
sent as a signal 124 to the mobile station radio unit 105.

An analog signal which is obtained by down-conversion
15 and quadrature demodulation of the channel frequency is
converted into a digital signal 126 by the A/D converter
106. The digital signal 126 is input to the sync
detection unit 117 of the signal processing unit 107
having a DSP, gate array, and standard cell. The sync
20 detection unit 117 sends a sync detection signal 127 to
the control unit 116 having a CPU.

The digital signal 126 sent from the A/D converter
106 is demodulated by the demodulation unit 118. A
demodulated signal 128 is sent to the deformat unit 119
25 where the signal 128 is deformatted. Deformatted data 129

is decoded by the decoding unit 120. A decoded signal 131 is sent to the output unit 108. The decoding unit 120 outputs CRC information 132 to the control unit 116.

The deformat unit 119 transfers a power detection
5 signal 130 to the power detection unit 121. The power detection unit 121 sends power detection information (RSSI) 133 to the control unit 116. The control unit 116 outputs a control signal 144 for controlling the frequency shift detection unit 114 and TCXO AFC unit 115 on the
10 basis of the sync detection signal 127, CRC information 132, and RSSI 133.

The deformat unit 119 transfers to the frequency shift detection unit 114 an AFC detection signal 134 prepared by gathering pilot signals to the same frequency.
15 The frequency shift detection unit 114 calculates a frequency shift from the AFC detection signal 134, and transfers a frequency shift value (Δf) 135 to the TCXO AFC unit 115. The frequency shift detection unit 114 intermittently operates under the control of the control
20 unit 116.

The TCXO AFC unit 115 adds a frequency shift value and updates the TCXO AFC value (Δf_{VCXO}) under the control of the control unit 116. The TCXO AFC value is transferred as a digital AFC signal 136 to the AFC D/A 112.
25 An AFC signal 137 D/A-converted by the AFC D/A 112 passes

through the LPF 111, and is input as an AFC signal 138 to the AFC terminal of the TCXO 109. Then, the oscillation frequency of the TCXO 109 is changed.

A signal 139 oscillated from the TCXO 109 is
5 converted by the mobile station PLL unit 110 into a plurality of signals having different frequencies. The mobile station PLL unit 110 supplies a signal 140 to the mobile station radio unit 105, a signal 141 to the A/D converter 106, a signal 142 to the signal processing unit
10 107, and a signal 143 to the AFC D/A 112.

In an idle time, intermittent operation is performed over a wide range in the whole mobile station 104 including the signal processing unit 107 and mobile station radio unit 105. In an idle time, the intermittent
15 operation of the TCXO AFC unit 115 determines the intermittent operation of the overall mobile station 104.

<First Embodiment>

Fig. 2 is a flow chart showing an AFC control flow in the first embodiment of the present invention. AFC
20 control operation generally starts when a portable radio terminal is powered on. The oscillation frequency of a mobile station oscillator 109 shifts due to degradation in temperature characteristic over time or the like.

A control unit 116 sets a minimum value T_{MIN} as an
25 intermittent operation period T in a frequency shift

detection unit 114 in advance, and sets 0 as a TCXO AFC value (Δf_{VCXO}) in a TCXO AFC unit 115 (step S201). If the frequency shift detection unit 114 detects Δf from an AFC detection signal 134 (step S202), the control unit 116
5 checks whether the detected Δf is larger than a predetermined value Δf_{tk1} (positive value) (step S203).

If the control unit 116 determines that Δf is Δf_{tk1} or less (NO in step S203), it checks whether the intermittent operation period T (minimum value T_{MIN} at this
10 time) set in the frequency shift detection unit 114 is larger than a predetermined maximum value T_{MAX} or more (step S204). Since the intermittent operation period set in the frequency shift detection unit 114 is the minimum value T_{MIN} , the control unit 116 determines that the
15 intermittent operation period T is smaller than T_{MAX} (NO in step S204), and sets an intermittent operation period twice the intermittent operation period T_{MIN} in the frequency shift detection unit 114 (step S205).

If Δf detected by the frequency shift detection unit
20 114 is a positive value, the control unit 116 adds a predetermined value Δf_{FIX} (positive value) to Δf_{VCXO} (0 at this time) to update the TCXO AFC value; or if Δf detected by the frequency shift detection unit 114 is a negative value, the control unit 116 adds a predetermined
25 value $-\Delta f_{FIX}$ to Δf_{VCXO} (0 at this time) to update the TCXO

AFC value (step S208).

If the control unit 116 determines in step S204 that the intermittent operation period T set in the frequency shift detection unit 114 is T_{MAX} or more (YES in step S204),
5 it does not change the intermittent operation period T . After that, if Δf detected by the frequency shift detection unit 114 is a positive value, the control unit 116 adds the predetermined value Δf_{FIX} (positive value) to Δf_{VCXO} to update the TCXO AFC value; or if Δf detected by
10 the frequency shift detection unit 114 is a negative value, the control unit 116 adds the predetermined value $-\Delta f_{FIX}$ to Δf_{VCXO} to update the TCXO AFC value (step S208).

If the control unit 116 determines in step S203 that Δf is larger than Δf_{tk1} (YES in step S203), it checks
15 whether the intermittent operation period T is the minimum value T_{MIN} or less (step S206). If the control unit 116 determines that the intermittent operation period T is larger than T_{MIN} (NO in step S206), it sets an intermittent operation period $1/2$ the current intermittent operation
20 period in the frequency shift detection unit 114 (step S207).

If Δf detected by the frequency shift detection unit 114 is a positive value, the control unit 116 adds the predetermined value Δf_{FIX} (positive value) to Δf_{VCXO} to
25 update the TCXO AFC value; or if Δf detected by the

frequency shift detection unit 114 is a negative value, the control unit 116 adds the predetermined value $-\Delta f_{\text{FIX}}$ to Δf_{VCXO} to update the TCXO AFC value (step S208).

If the control unit 116 determines in step S206 that
5 the intermittent operation period T is T_{MIN} or less (YES in step S206), it does not change the current intermittent operation period T . Then, if Δf detected by the frequency shift detection unit 114 is a positive value, the control unit 116 adds the predetermined value Δf_{FIX}
10 (positive value) to the TCXO AFC value (Δf_{VCXO}) of the TCXO AFC unit 115; or if Δf detected by the frequency shift detection unit 114 is a negative value, the control unit 116 adds the predetermined value $-\Delta f_{\text{FIX}}$ to the TCXO AFC value (Δf_{VCXO}) of the TCXO AFC unit 115 (step S208).

15 (a) in Fig. 3 shows a control signal output from the control unit 116 to the frequency shift detection unit 114, a period τ during which the frequency shift detection unit 114 is ON, and the intermittent operation period T of the frequency shift detection unit 114. (b) shows the
20 state of the control signal when the intermittent operation period T is set $1/2$ in step S207 of Fig. 2. (c) shows the state of the control signal when the intermittent operation period T is set twice in step S205 of Fig. 2.

25 (d-1) to (d-3) show an example of a control signal

output from the control unit 116 in the operation in the flow chart of Fig. 2. (d-1) shows that the frequency shift detection unit 114 is operated while the intermittent operation period T is changed. (d-2) shows
5 Δf detected by the frequency shift detection unit 114 at that time. (d-3) shows the value Δf_{VCXO} output from the TCXO AFC unit 115. At this time, T_{MIN} is $1/2 T_{MAX}$.

<Second Embodiment>

Fig. 4 is a flow chart showing an AFC control flow in
10 the second embodiment of the present invention. AFC control operation generally starts when a portable radio terminal is powered on. The oscillation frequency of a mobile station oscillator 109 shifts due to degradation in temperature characteristic over time or the like.

15 A control unit 116 sets N-1 (N: predetermined repeat number) in flag, and sets 0 as a TCXO AFC value (Δf_{VCXO}) in a TCXO AFC unit 115 (step S401). If a frequency shift detection unit 114 detects Δf (step S402), the control unit 116 checks whether the detected Δf is a
20 predetermined value Δf_{tk2} (positive value) or more (step S403).

If the control unit 116 determines that Δf is Δf_{tk2} or more (YES in step S403), it registers in the TCXO AFC unit 115 a new TCXO AFC value obtained by adding Δf to Δf_{VCXO} , and registers N-1 in flag again (step S404).
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If the control unit 116 determines that Δf is smaller than Δf_{tk2} (NO in step S403), it checks whether flag is 0 (step S405). Since flag is N-1, the control unit 116 determines that flag is not 0 (NO in step S405),
5 and checks whether the currently detected Δf and the previously detected Δf , i.e., Δf_p (flag) have the same sign (step S407).

If the control unit 116 determines in step S407 that the currently detected Δf and the previously detected Δf
10 have the same sign (YES in step S407), it decrements flag by 1, and registers the currently detected Δf as Δf_p (flag) (step S408).

If the control unit 116 determines in step S407 that the currently detected Δf and the previously detected Δf
15 do not have the same sign (NO in step S407), it registers N-1 in flag, and registers the currently detected Δf as Δf_p (flag) (step S409).

If the control unit 116 determines in step S405 that flag is 0 (YES in step S405), it registers as the TCXO AFC
20 value a value obtained by adding to Δf_{vcxo} the average of Δf detected N times by the frequency shift detection unit 114, registers N-1 in flag, and registers the currently detected Δf as Δf_p (flag) (step S406).

In the second embodiment, if the detected frequency
25 shift Δf is smaller than the predetermined value Δf_{tk2} ,

the value Δf is reflected on Δf_{VCXO} only when frequency shifts Δf of the same sign are successively detected N times. Although noise attains a larger influence for a smaller frequency shift, a malfunction by inputting an erroneous value Δf to the TCXO AFC unit 115 can be avoided.

<Third Embodiment>

Fig. 5 is a flow chart showing an AFC control flow in the third embodiment of the present invention. AFC control operation generally starts when a portable radio terminal is powered on. The oscillation frequency of a mobile station oscillator 109 shifts due to degradation in temperature characteristic over time or the like.

A control unit 116 sets 0 as a TCXO AFC value (Δf_{VCXO}) in a TCXO AFC unit 115 (step S501). If a frequency shift detection unit 114 detects Δf (step S502), the control unit 116 checks on the basis of sync information from a sync detection unit 117 whether the communication state has stepped out (step S503). If the control unit 116 determines that the communication state has stepped out when the frequency shift detection unit 114 detects Δf (YES in step S503), the control unit 116 counts a timer for a predetermined period to establish synchronization (step S504), and executes processing from step S501.

If the control unit 116 determines in step S503 that

the communication state is in sync (NO in step S503), it checks whether RSSI output from a power detection unit 121 is larger than a predetermined value $RSSI_{tk}$ (step S505). If the control unit 116 determines that RSSI is larger
5 than $RSSI_{tk}$ (YES in step S505), it registers the sum of Δf_{vcxo} and Δf as the TCXO AFC value in the TCXO AFC unit 115 (step S506). If the control unit 116 determines in step S505 that RSSI is $RSSI_{tk}$ or less (NO in step S505), it determines that the obtained value Δf is low in
10 reliability because of a small power of a received signal, and does not update Δf_{vcxo} .

<Fourth Embodiment>

Fig. 6 is a flow chart showing an AFC control flow in the fourth embodiment of the present invention. AFC
15 control operation generally starts when a portable radio terminal is powered on. The oscillation frequency of a mobile station oscillator 109 shifts due to degradation in temperature characteristic over time or the like.

A control unit 116 sets 0 as a TCXO AFC value (Δf_{vcxo}) in a TCXO AFC unit 115 (step S601). If a frequency
20 shift detection unit 114 detects Δf (step S602), the control unit 116 checks on the basis of sync information from a sync detection unit 117 whether the communication state has stepped out (step S603). If the control unit
25 116 determines that the communication state has stepped

out when the frequency shift detection unit 114 detects Δf (YES in step S603), the control unit 116 counts a timer for a predetermined period to establish synchronization (step S604), and executes processing from step S601.

5 If the control unit 116 determines in step S603 that the communication state is in sync (NO in step S603), and determines from CRC (Cyclic Redundancy Check) information obtained by a decoding unit 120 that the transmission frame does not contain any error (YES in step S605), the
10 control unit 116 registers the sum of Δf_{VCXO} and Δf as the TCXO AFC value in the TCXO AFC unit 115 (step S606). If the control unit 116 determines from CRC information that the transmission frame contains an error (NO in step S605), it determines that the obtained value Δf is low in
15 reliability because of a poor transmission channel state between a base station 101 and a portable radio apparatus, and does not update Δf_{VCXO} .

<Fifth Embodiment>

Fig. 7 is a flow chart showing an AFC control flow in
20 the fifth embodiment of the present invention. AFC control operation generally starts when a portable radio terminal is powered on. The oscillation frequency of a mobile station oscillator 109 shifts due to degradation in temperature characteristic over time or the like.

25 A control unit 116 sets a minimum value T_{MIN} as an

intermittent operation period T in a frequency shift detection unit 114 in advance, and sets 0 as a TCXO AFC value in frequency shift detection unit 114 (step S701). The control unit 116 checks whether RSSI output from a power detection unit 121 is larger than a predetermined value $RSSI_{tk2}$ (step S702).

If the control unit 116 determines in step S702 that RSSI is $RSSI_{tk2}$ or less (NO in step S702), it determines that the oscillation frequency of the TCXO 109 may have greatly shifted, sets the minimum value T_{MIN} as an intermittent operation period (step S703), and performs AFC at a short period. If the frequency shift detection unit 114 detects Δf (step S704), the control unit 116 checks whether the detected value Δf is larger than a predetermined value Δf_{tk1} (positive value) (step S705).

If the control unit 116 determines that Δf is Δf_{tk1} or less (NO in step S705), it checks whether the intermittent operation period T (minimum value T_{MIN} at this time) set in the frequency shift detection unit 114 is a predetermined maximum value T_{MAX} or more (step S706). Since the intermittent operation period set in the frequency shift detection unit 114 is the minimum value T_{MIN} , the control unit 116 determines that the intermittent operation period T is smaller than T_{MAX} (NO in step S706), and sets an intermittent operation period twice the

intermittent operation period T_{MIN} in the frequency shift detection unit 114 (step S707).

If Δf detected by the frequency shift detection unit 114 is a positive value, the control unit 116 adds a
5 predetermined value Δf_{FIX} (positive value) to Δf_{VCXO} (0 at this time) to update the TCXO AFC value; or if Δf detected by the frequency shift detection unit 114 is a negative value, the control unit 116 adds a predetermined value $-\Delta f_{\text{FIX}}$ to Δf_{VCXO} (0 at this time) to update the TCXO
10 AFC value (step S710).

If the control unit 116 determines in step S706 that the intermittent operation period T set in the frequency shift detection unit 114 is T_{MAX} or more (YES in step S706), it does not change the intermittent operation period T .
15 Then, if Δf detected by the frequency shift detection unit 114 is a positive value, the control unit 116 adds the predetermined value Δf_{FIX} (positive value) to Δf_{VCXO} to update the TCXO AFC value; or if Δf detected by the frequency shift detection unit 114 is a negative value,
20 the control unit 116 adds the predetermined value $-\Delta f_{\text{FIX}}$ to Δf_{VCXO} to update the TCXO AFC value (step S710).

If the control unit 116 determines in step S705 that Δf is larger than Δf_{tk1} (YES in step S705), it checks whether the intermittent operation period T is the minimum
25 value T_{MIN} or less (step S708). If the control unit 116

determines that the intermittent operation period T is larger than T_{MIN} (NO in step S708), it sets an intermittent operation period $1/2$ the current intermittent operation period in the frequency shift detection unit 114 (step S709).

If Δf detected by the frequency shift detection unit 114 is a positive value, the control unit 116 adds the predetermined value Δf_{FIX} (positive value) to Δf_{VCXO} to update the TCXO AFC value; or if Δf detected by the frequency shift detection unit 114 is a negative value, the control unit 116 adds the predetermined value $-\Delta f_{FIX}$ to Δf_{VCXO} to update the TCXO AFC value (step S710).

If the control unit 116 determines in step S708 that the intermittent operation period T is T_{MIN} or less (YES in step S708), it does not change the current intermittent operation period T . Then, if Δf detected by the frequency shift detection unit 114 is a positive value, the control unit 116 adds the predetermined value Δf_{FIX} (positive value) to the TCXO AFC value (Δf_{VCXO}) of the TCXO AFC unit 115; or if Δf detected by the frequency shift detection unit 114 is a negative value, the control unit 116 adds the predetermined value $-\Delta f_{FIX}$ to the TCXO AFC value (Δf_{VCXO}) of the TCXO AFC unit 115 (step S710).